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Square concrete filled steel tubular (CFST) members under loading and chloride corrosion: Experiments

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ABSTRACT

This paper is an attempt to study the performance of concrete filled steel tubular (CFST) members with square sections under both loading and chloride corrosion. A total of 28 specimens, including 17 stub columns and 11 beams, were tested. The main parameters were loading ratio (from 0 to 0.75) during corrosion, as well as corrosion condition (no corrosion, and fully or half immersed into corrosive solution, respectively). According to the test, the effects of both loading and corrosion on the behaviour of CFST and reference hollow steel tubular members were analyzed. Comparisons between the predicted ultimate strength by using the existing codes of DBJ/T13-51-2010 and EC4-2004 and the testing results were proposed.

1. Introduction

Concrete filled steel tubular (CFST) structures have several well known structural and constructional benefits (Han, 2010 [1], Shanmugam and Lakshmi, 2001 [2]), they thus have an increasing application in a large amount of the recent offshore structures, bridge and tower structures.

CFST structures at service loads will suffer the effects of both shrinkage and creep of the core concrete. In some offshore and bridge structures, CFST may also subjected to chloride corrosion. Fig. 1 shows a transmission tower with 370 m in height in China, where four CFST ribs are used as main components. This tower locates close to the East China Sea, durability design of CFST ribs is one of the key issues for this structure. Thus, it is important to study the behaviour of CFST members under both loading and chloride corrosion.

In the past, there were some research studies carried out on CFST members under long-term sustained loading, such as Furlong (1967) [3], Terrey et al. (1994) [4], Morino et al. (1996) [5], Uy (2001) [6], Ichinose et al. (2001) [7], Han et al. (2004) [8], Kwon et al. (2007) [9], and etc. It was found that, the influencing of long-term sustained loading on the ultimate strength of CFST columns are not negligible. Han et al. (2004) [8] proposed a strength index k_{cr} to quantify the effects of the long-term sustained loading, k_{cr} was expressed as:

$$k_{cr} = \frac{N_{ul}}{N_{ue-shortterm}} \quad (1)$$

where, N_{ul} is the ultimate strength of CFST columns subjected to long-term sustained loading, $N_{ue\text{-}shortterm}$ is the strength of the referred member without long-term sustained loading.

Studies on constructional steel and steel tubular structures subjected to corrosive environment were also carried out in the past (Melchers, 2006 [10], 2010 [11]; Ma et al., 2009 [12]). It is known that seawater marine environment is in particular highly corrosive for common steel, whilst chloride ion is one of the most significant natural contaminant which plays an important role in the corrosion process of structural steel. Table 1 shows some of the existing codes of steel structures from several countries or regions as well as their suggested guidance on corrosion protection methods. These codes listed in Table 1 have explicitly referred to the significant role of marine corrosion and suggested measures to ensure that the structures are able to perform their function during the service life (50 years' design working life, as specified in all the listed codes) ([13–19]). The guidance suggested can be generally summarized as three types:

- Use of protective systems, such as paints, sacrificial coatings, and et al.;
- Use of suitable non-rusting materials, such as weathering steel, alloy, and et al.;
- Use of electrochemical protection, such as impressed current cathodic protection, and et al.

Besides these protective methods mentioned above, in some cases, the use of a sacrificial corrosion allowance is also recommended by structural engineers and researchers. This method suggests that

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Nomenclature

A_c	Cross-sectional area of concrete
A_s	Cross-sectional area of steel tube
A_{se}	Cross-sectional area of steel tube after corrosion
B	Width of tube section
B_e	Width of tube section after corrosion
DI	Ductility index
E_c	Elastic modulus of concrete
E_s	Elastic modulus of steel
f_{cu}	Cube strength of concrete
f_u	Ultimate strength of steel
f_y	Yield strength of steel
L	Length of specimen
L_0	Calculating span of beam
M	Bending moment
m	Loading ratio of beam ($=M_l/M_u$)
M_{uc}	Predicted flexural strength of beam
M_{ue}	Measured flexural strength of beam
N	Axial load
n	Loading ratio of column ($=N_l/N_u$)
N_l	Long-term sustained load applied on column during the corrosion test
N_{uc}	Predicted ultimate strength of column
N_{ue}	Measured ultimate strength of column
P_l	Long-term sustained load applied on beam during the corrosion test
t	Sustaining days of long-term sustained loading and corrosion
t_s	Wall thickness of steel tube
t_{sc}	Wall thickness of steel tube after corrosion
u_m	Mid-span deflection of beam
u_{mlc}	Mid-span deflection increment of beam during long-term sustained loading and corrosion test
ε_y	Yield strain of steel
ρ	Concentration of NaCl solution
Δ	Axial deformation of stub column
Δ_{lc}	Axial deformation increment of stub column during long-term sustained loading and corrosion test
Δt_s	Wall thickness loss of steel tube due to corrosion
ξ	Confinement factor ($=A_s f_y/A_c f_{ck}$)
ξ_e	Effective confinement factor after corrosion ($=A_{se} f_y/A_c f_{ck}$)
μ_s	Poisson's ratio of steel

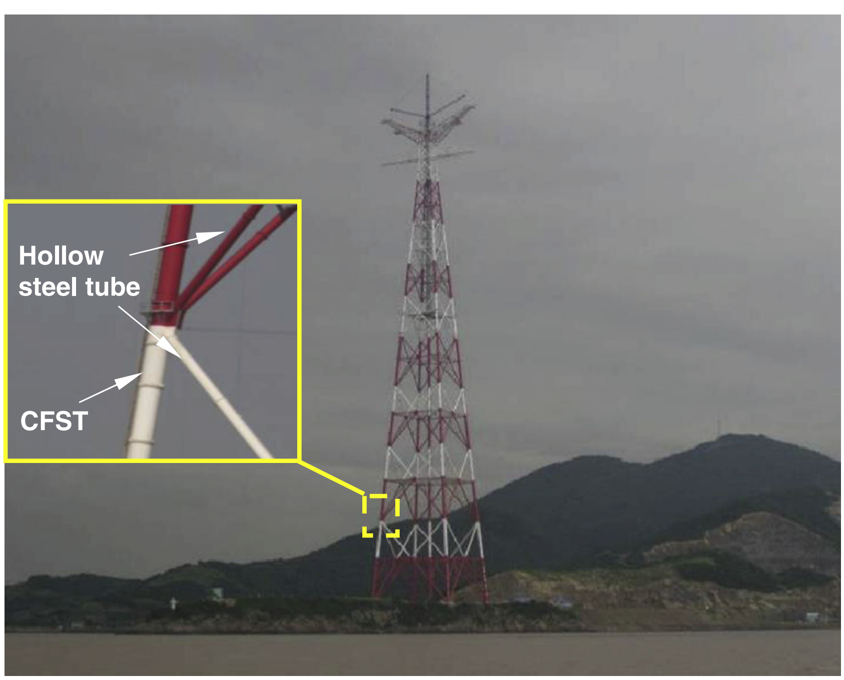

Fig. 1. Photo of an offshore CFST structure.